

Figure 1: Categories of Defects in Sewer Pipes



Figure 2: Root Intrusion

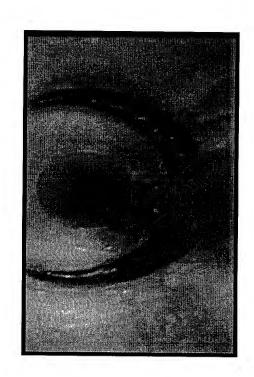


Figure 4: Infiltration



Figure 3: Dirt Deposits

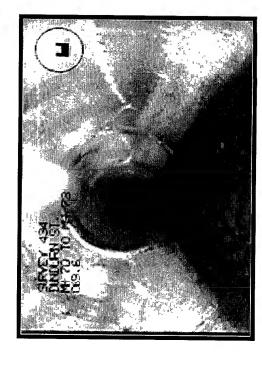


Figure 5: Cracks

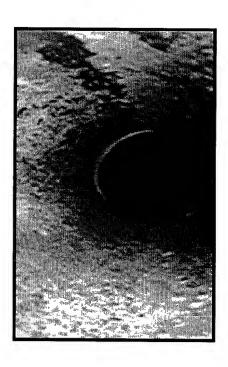


Figure 6: Misalignments

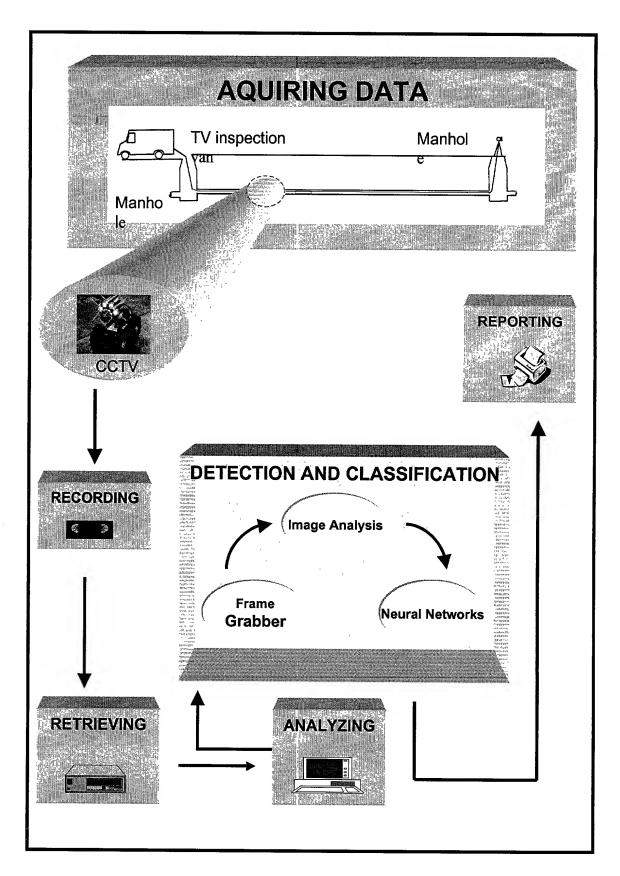


Figure 7: Proposed Automated Detection and Classification System

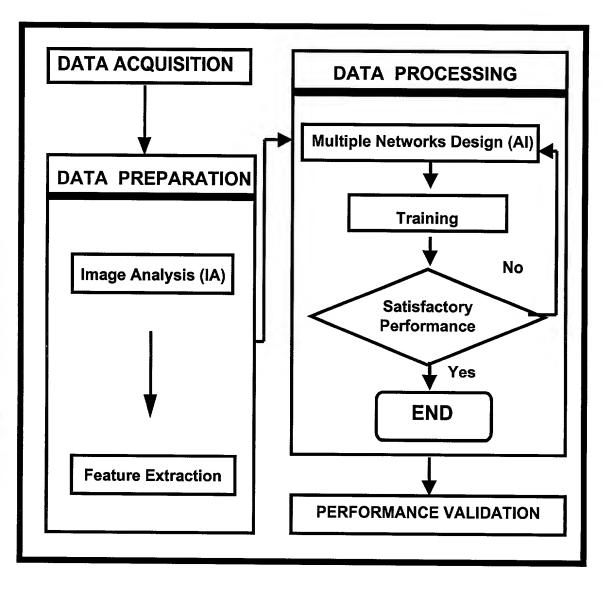


Figure 8: Methodology for Developing Automated Detection System

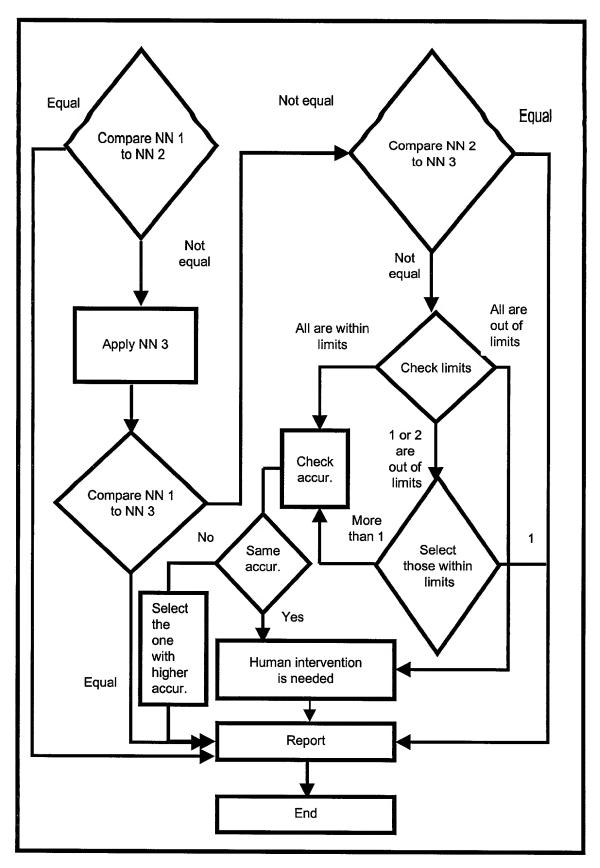


Figure 9: Algorithm of the Multiple Classifier System

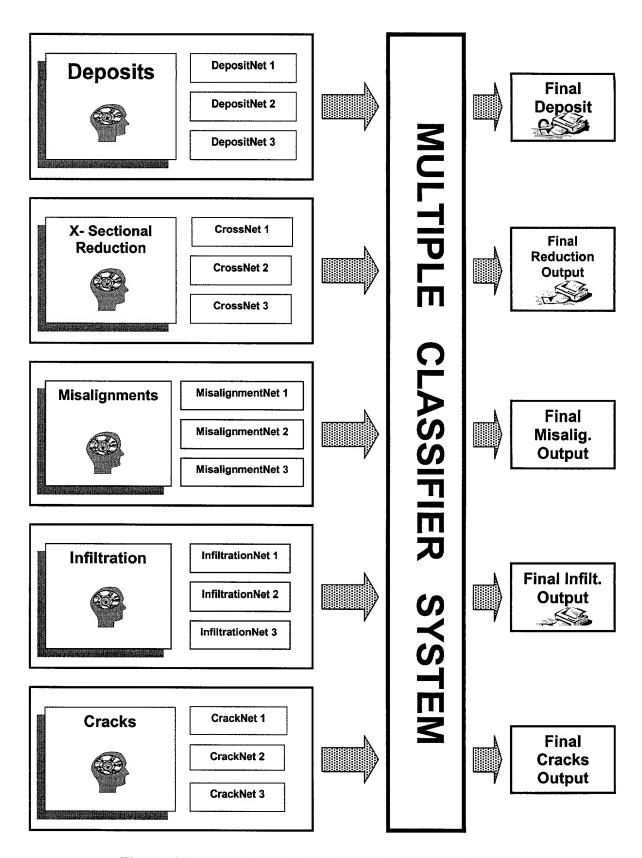


Figure 3-10: Utilization of the Multiple Classifier System

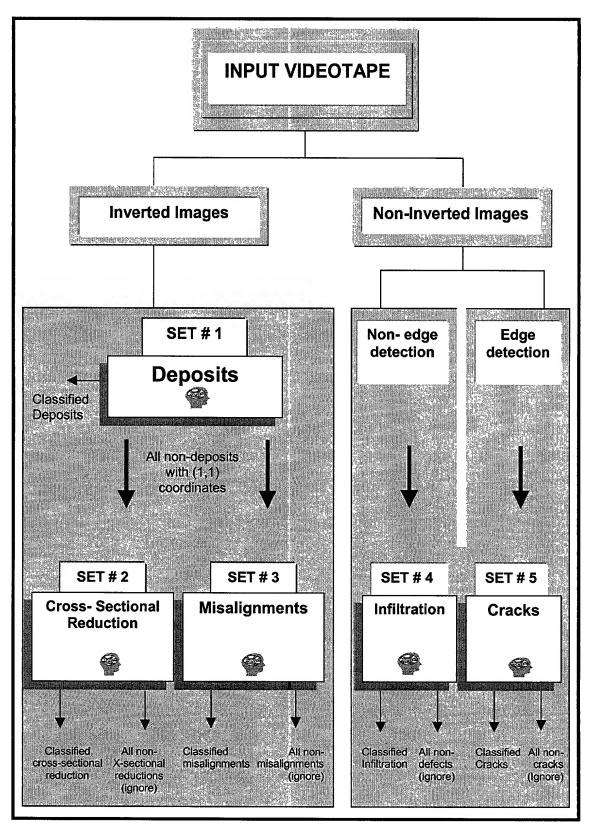


Figure 3-11: Solution Strategy

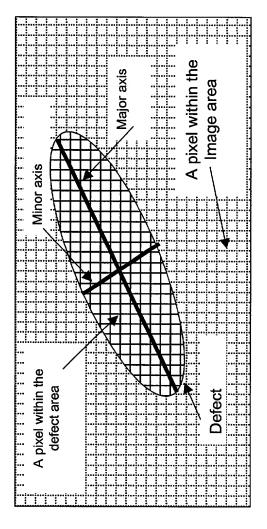


Figure 12: Geometrical Attributes of Defects

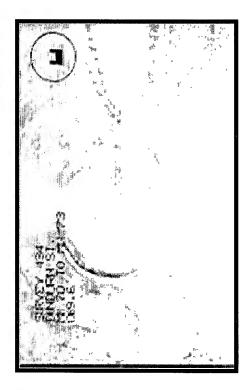


Figure 13: Background Subtracted Image of Cracks



Figure 15: Dilated Image of Cracks

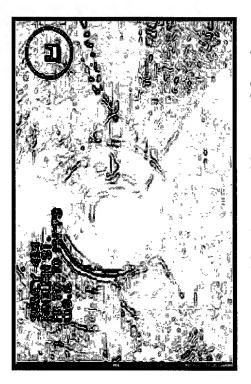


Figure 14: Edge Detected Image of Cracks



Figure 16: Thresholded Image of Cracks



Figure 17: Segmented Image of Cracks

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243.00	128.24	43.82	219.07	7.	41	104.81	28.39
136.00	111.10	21.24	244.56	4	8	65.70	17.86
2159.00	188.20	70.57	282.51	A 35.	25	368.13	61.65
292.00	131.72	32.81	202.45	7.71	89	89.01	31.38
192.00	109.64	23.06	202.17	51.	32	118.71	24.13
241.00	130.94	42.37	178.54	65	96	101.64	23.34
1345.00	168.22	65.38	259.09	8	22	399.50	95.43
185.00	140.76	49.97	205.39	84.36	98	68.87	17.46
356.00	143.16	44.28	176.45	103.	95	96.43	29.89
177.00	137.53	39.02	201.72	105.	25	56.63	18.03
591.00	142.98	50.42	37.24	123.	74	175.10	51.35
4009.00	145.72	47.18	281.45	174.	4.	761.11	88.82
251.00	136.23	42.46	186.72	144.	77	90.08	30.47
136.00	119.99	31.48	88.65	158.	98	59.84	22.41

Figure 18: Analysis Results of an Image Depicting Cracks

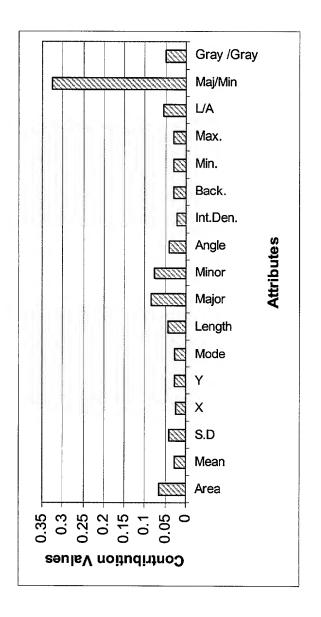


Figure 19: Contribution Values of Attributes Utilized in Designing the Preliminary Neural Network for Classification of Cracks

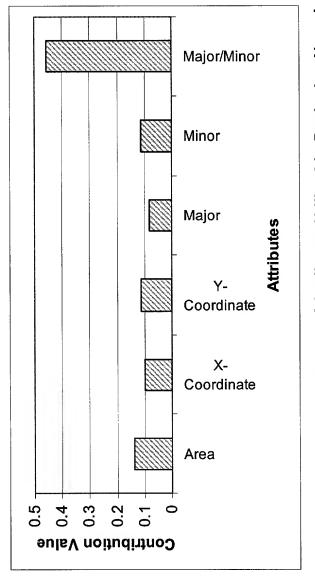


Figure 20: Contribution Values of Attributes Utilized in Designing Neural Network # 1 for Classification of Cracks

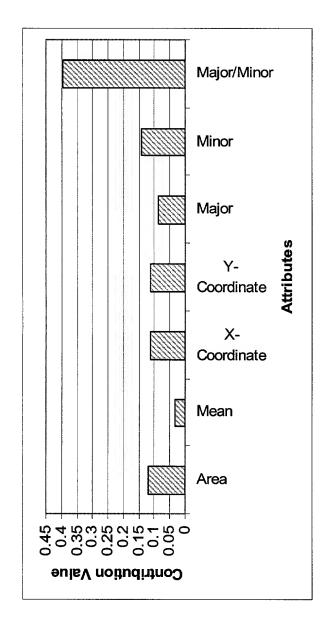


Figure 21: Contribution Values for the Selected Attributes Utilized in Designing CrackNet 2

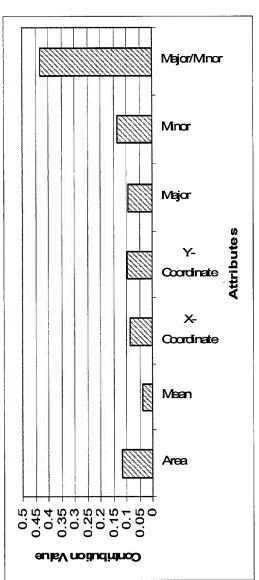


Figure 22: Contribution Values for the Selected Attributes Utilized in Designing CrackNet 3



Figure 23: Segmented Image of a Case Example on Cracks

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Figure 24: Output Results of a Case example on Cracks

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Figure 25: Thresholded Output Results of a Case example on Cracks

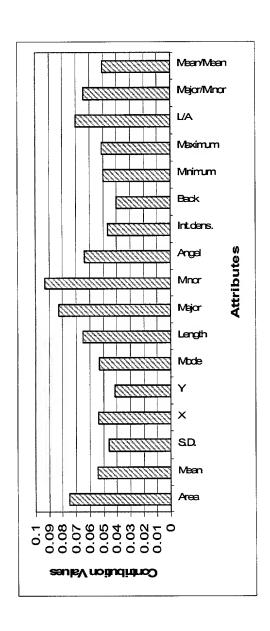


Figure 26: Contribution Values of Attributes Utilized in Designing InfiltrationNet 1



Figure 27: Dilated Image of Infiltration



Figure 29: Thresholded Image of Infiltration

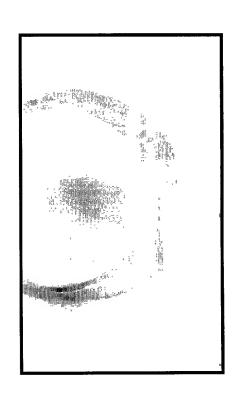


Figure 28: Background subtracted Image of Infiltration

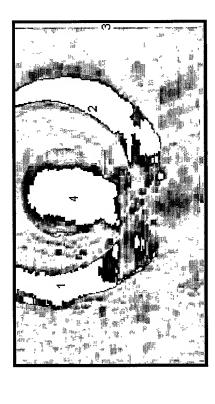


Figure 30: Segmented Image of Infiltration

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က်	492.00	55.05	34.63	318.00	=	81.50	332.24	185.05
4 ;	3609.00	49.03	13.20	159.46		56.57	343.61	87.67

Figure 31: Analysis Results of an Image Depicting Infiltration

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Figure 32: Classification Results of a Case Example on Infiltration

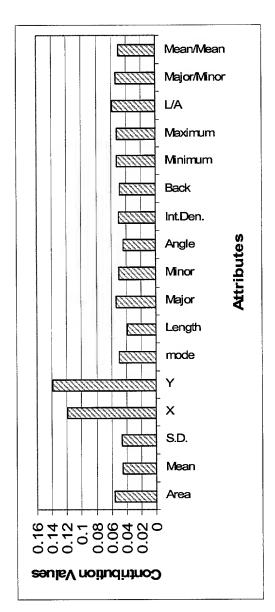


Figure 33: Contribution Values of Attributes Utilized in Designing DepositNet 1

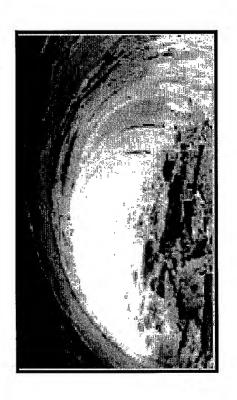


Figure 34: Inverted Image of Deposits

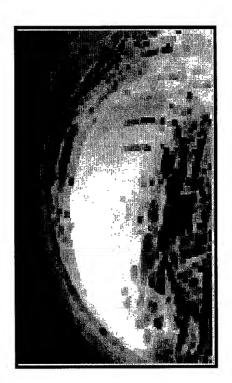


Figure 36: Dilated Image of Deposits



Figure 35: Background Subtracted Image of Deposits



Figure 37: Thresholded Image of Deposits

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Figure 38: Segmented Image of Deposits

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Figure 39: Analysis Results of an Image Depicting Deposits

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Figure 40: Classification Results of a Case Example on Deposits

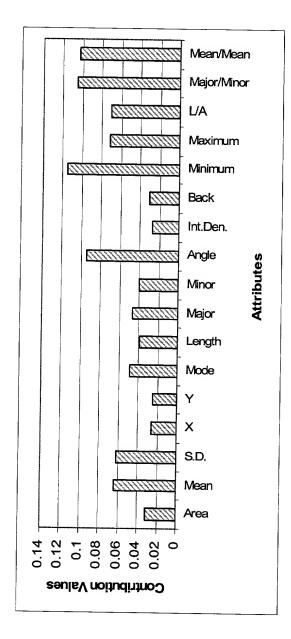


Figure 41: Contribution Values for all Attributes Utilized in Designing a Preliminary Neural Network for Classification of Cross-sectional Reductions



Figure 42: Inverted Image of cross-sectional Reductions



Figure 44: Background subtracted Image of Cross-sectional Reductions



Figure 43: Dilated Image of cross-sectional Reductions



Figure 45: Thresholded Image of Cross-Sectional Reductions



Figure 46: Segmented Image of Cross-sectional Reductions

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Figure 47: Analysis Results of an Image Depicting Cross-sectional Reductions

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Figure 48: Classification Results of a Case Example on Cross-sectional Reductions

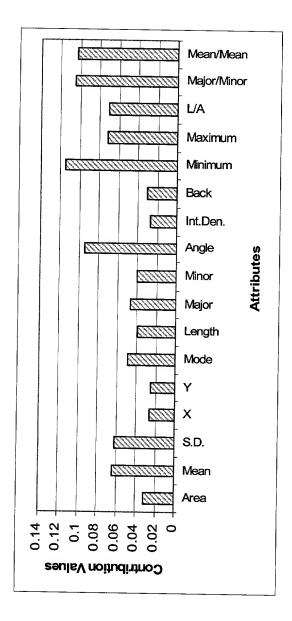


Table 49: Initial Parameters Used in Designing a Preliminary Neural Network for Classification of Misalignments

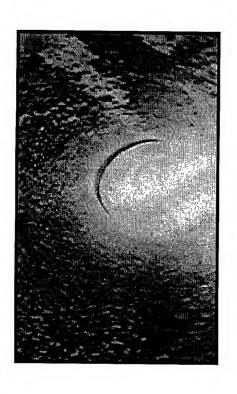


Figure 50: Inverted Image of Misalignments



Figure 52: Background Substracted Image of Misalignments

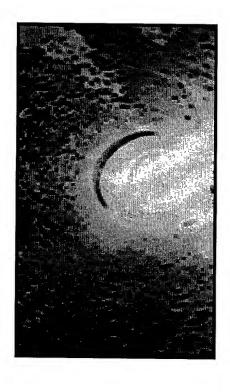


Figure 51: Dilated Image of Misalignments

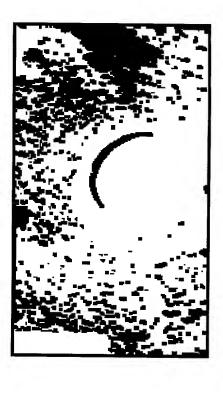


Figure 53: Thresholded Image Misalignments

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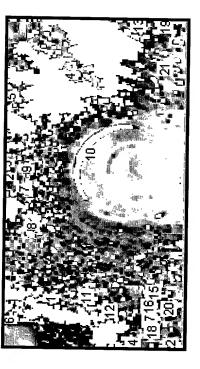


Figure 54: Segmented Image of Misalignments

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4.	6979.00	65.86	23.03	254.26	56.42	1431.09	127.44
s.	151.00	50.42	10.84	234.46	6.10	76.77	16.84
	63.00	42.86	3.46	24.00	7.59	43.46	14.36
۲.	147.00	52.41	17.64	148.17	18.16	73.60	16.54
 	315.00	49.34	12.66	113.77	25.18	172.99	22.07
۶.	77.00	45.30	10.39	166.31	20.26	51.46	11.32
	524.00	61.37	24.96	181.44	75.00	212.65	46.55
ij	77.00	44.99	6.90	47.45	72.77	49.46	16.56
.;	51.00	43.12	3.41	34.14	92.31	34.97	11.00
e,	96.00	61.27	22.01	303.91	113.18	44.73	15.06
4.	61.00	44.38	3.60	2.20	112.74	31.90	12.69
۲,	186.00	51.23	16.69	52.42	129.34	115.15	19.32
	86.00	55.33	14.79	39.26	125.14	39.80	15.82
۲.	82.00	43.87	5.03	25.78	126.00	52.87	15.35
18.	97.00	44.66	5.31	15.62	128.27	57.46	12.62
φ.	187.00	53.84	19.02	302.75	136.37	98.77	24.82
	170.00	60.12	19.48	37.32	142.69	65.94	21.02
٦.	59.00	99.09	30.58	262.57	136.07	33.21	10.31
نہ	89.00	46.31	7.62	2.34	144.67	55.31	17.46

Figure 55: Analysis Results of an Image Depicting Misalignments

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Figure 56: Classification Results of a Case example on Misalignments

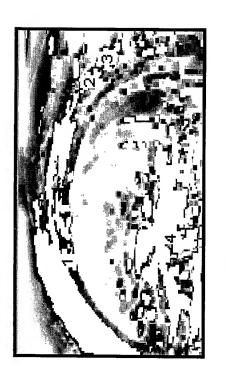


Figure 57: Segmented Image of Deposits

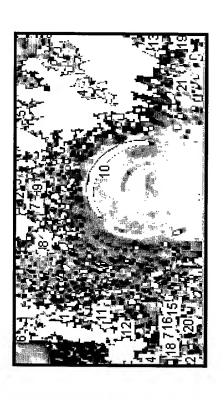


Figure 58: Segmented image of Misalignments



Figure 59: Segmented Image of Cross-sectional Reductions

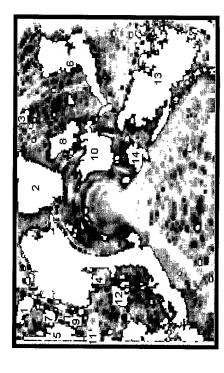


Figure 60: Segmented Image of Cracks



Figure 61: Segmented Image of Infiltration

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Figure 62: Output Results of a Case Example on Deposits Utilizing DepositNet 1 and the Solution Strategy Module

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Figure 62: Output Results of a Case Example on Deposits Utilizing DepositNet 1 and the Solution Strategy Module (Continued)

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Figure 63: Output Results of a Case Example on Deposits Utilizing DepositNet 2 and the Solution Strategy Module

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Figure 63: Output Results of a Case Example on Deposits Utilizing DepositNet 2 and the Solution Strategy Module (Continued)

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Figure 64: Output Results of a Case Example on Deposits Utilizing DepositNet 3 and the Solution Strategy Module

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Figure 64: Output Results of a Case Example on Deposits Utilizing DepositNet 3 and the Solution Strategy Module (Continued)

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Figure 65: Comparison of Output Results of DepositNet 1-3 Utilizing the Multiple Classifier Module

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Figure 65: Comparison of Output Results of DepositNet 1-3 Utilizing the Multiple Classifier Module (Continued)

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Figure 66: Output Results of a Case Example on Cross-sectional Reductions Utilizing CrossNet 1 and the Solution Strategy

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Figure 67: Output Results of a Case Example on Cross-sectional Reductions Utilizing CrossNet 2 and the Solution Strategy

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Figure 68: Output Results of a Case Example on Cross-sectional Reductions Utilizing CrossNet 3 and the Solution Strategy Module

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Figure 69: Comparison of Output Results of CrossNet 1-3 Utilizing the Multiple Classifier Module

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Figure 70: Output Results of a Case Example on Misalignments Utilizing MisalignmentNet 1 and the Solution Strategy Module

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Figure 71: Output Results of a Case Example on Misalignments Utilizing MisalignmentNet 2 and the Solution Strategy Module

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Figure 72: Output Results of a Case Example on Misalignments Utilizing MisalignmentNet 3 and the Solution Strategy

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Figure 73: Comparison of Output Results of MisalignmentNet 1-3 Utilizing the Multiple Classifier Module



Figure 74: Segmented Image of Cracks

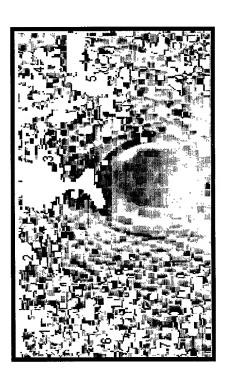


Figure 76:Segmented Image of Misalignments



Figure 75: Segmented Image of Cross-sectional Reductions



Figure 77: Segmented image of Deposits

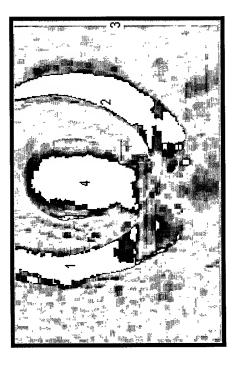


Figure 78: Segmented Image of Infiltration

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Figure 79: Output Results of a Case Example on Infiltration Utilizing InfiltrationNet 1 and the Solution Strategy Module

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Figure 79: Output Results of a Case Example on Infiltration Utilizing InfiltrationNet 1 and the Solution Strategy Module (Continued)

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Figure 80: Output Results of a Case Example on Infiltration Utilizing InfiltrationNet 2 and the Solution Strategy Module

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Figure 80: Output Results of a Case Example on Infiltration Utilizing InfiltrationNet 2 and the Solution Strategy Module (Continued)

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Figure 81: Output Results of a Case Example on Infiltration Utilizing InfiltrationNet 3 and the Solution Strategy Module

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Figure 81: Output Results of a Case Example on Infiltration Utilizing InfiltrationNet 3 and the Solution Strategy Module (Continued)

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Figure 82: Comparison of Output Results of InfiltrationNet 1-3 Utilizing the Multiple Classifier Module

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Figure 82: Comparison of Output Results of InfiltrationNet 1-3 Utilizing the Multiple Classifier Module (Continued)

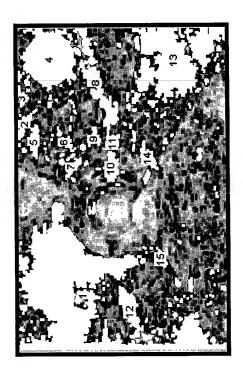


Figure 83: Segmented Image of Cracks



Figure 85: Segmented Image of Misalignments

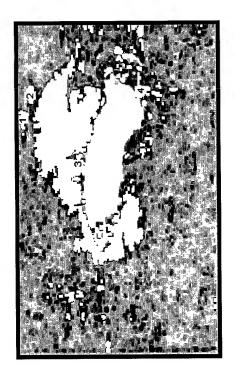


Figure 84: Segmented Image of Cross-sectional Reductions



Figure 86: Segmented Image of Deposits

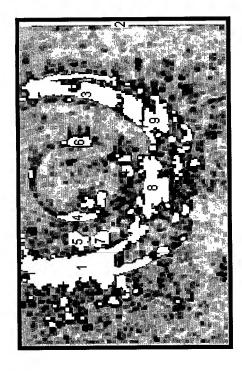


Figure 87: Segmented Image of Infiltration

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Figure 88: Output Results of a Case Example on Cracks Utilizing CrackNet 1 and the Solution Strategy Module

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Figure 88: Output Results of a Case Example on Cracks Utilizing CrackNet 1 and the Solution Strategy Module (Continued)

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Figure 89: Output Results of a Case Example on Cracks Utilizing CrackNet 2 and the Solution Strategy Module

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Figure 89: Output Results of a Case Example on Cracks Utilizing CrackNet 2 and the Solution Strategy Module (Continued)

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Figure 90: Output Results of a Case Example on Cracks Utilizing CrackNet 3 and the Solution Strategy Module

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Figure 90: Output Results of a Case Example on Cracks Utilizing CrackNet 3 and the Solution Strategy Module (Continued)

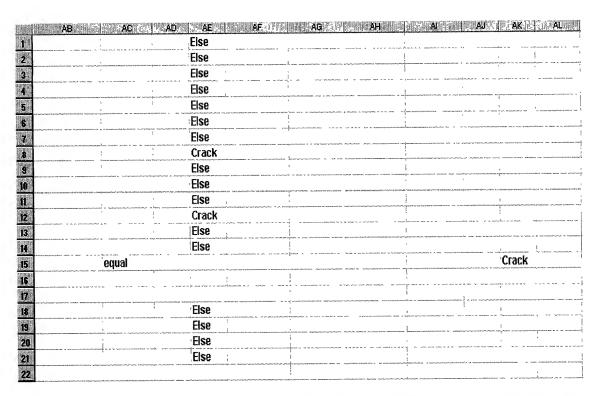


Figure 91: Comparison of Output Results of CrackNet 1-3 Utilizing the Multiple Classifier Module

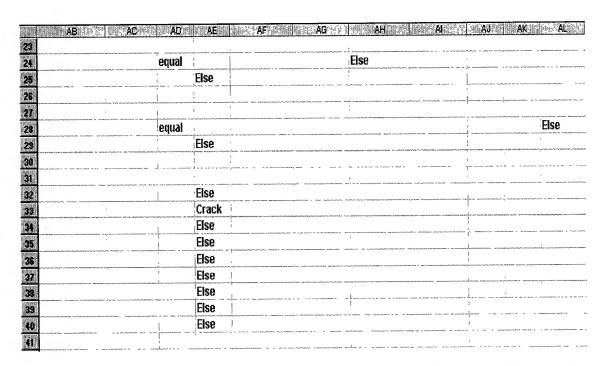


Figure 91: Comparison of Output Results of CrackNet 1-3 Utilizing the Multiple Classifier Module (Continued)

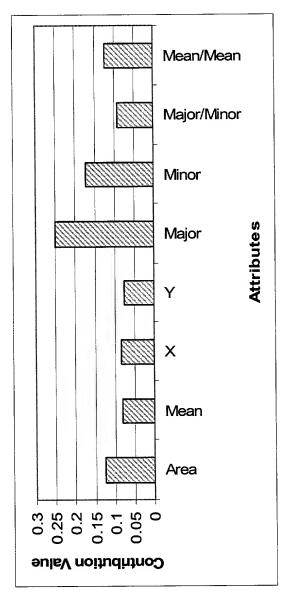


Figure 108: Contribution Values of Attributes Utilized in Designing InfiltrationNet 2

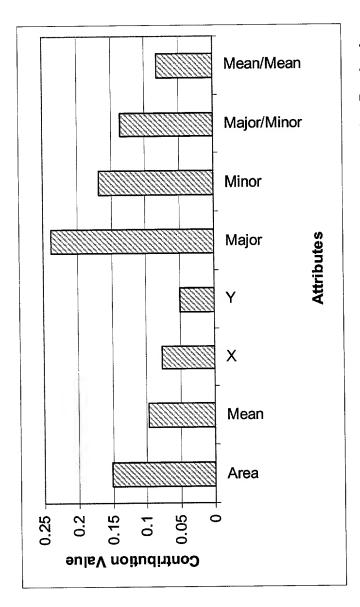


Figure 109: Contribution Values of Attributes Utilized in Designing InfiltrationNet 3

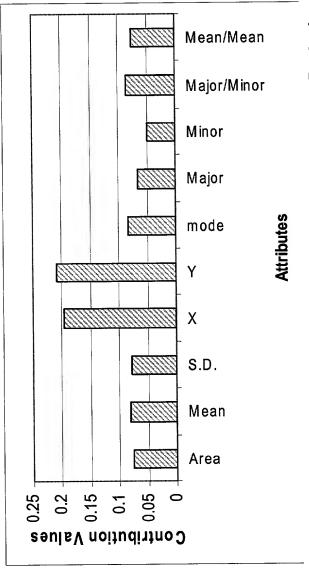


Figure 110: Contribution Values of Attributes Utilized in Designing DepositNet 2

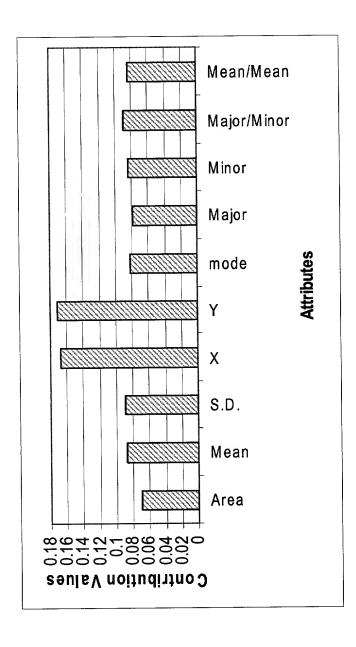


Figure 111: Contribution Values of Attributes Utilized in Designing DepositNet 3

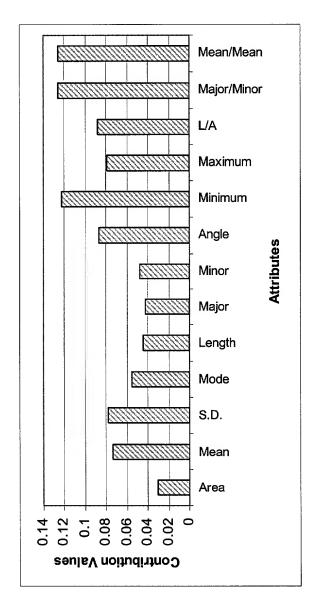


Figure 112: Contribution Values of Attributes Utilized in Designing CrossNet 1

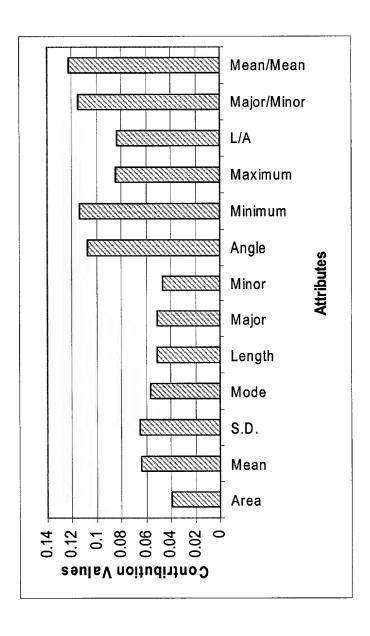


Figure 113: Contribution Values of Attributes Utilized in Designing CrossNet 2

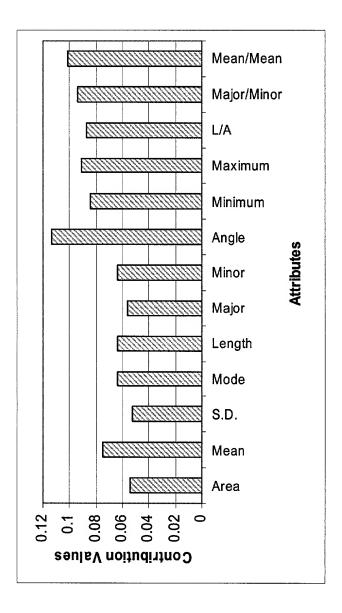


Figure 114: Contribution Values of Attributes Utilized in Designing CrossNet 2

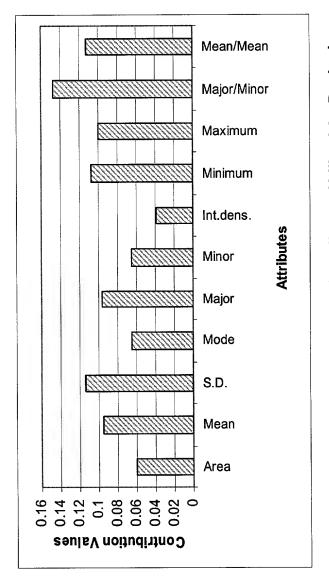


Figure 115: Contribution Values of Attributes Utilized in Designing AlignmentNet 1

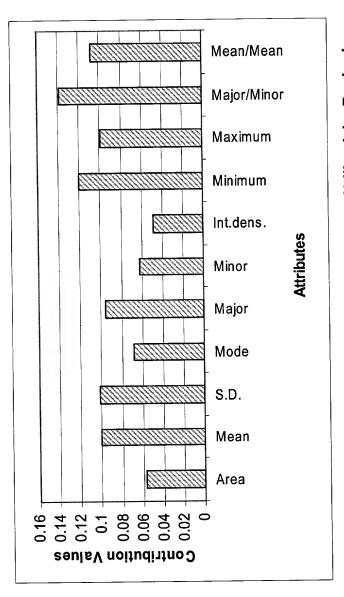


Figure 116: Contribution Values of Attributes Utilized in Designing AlignmentNet 2

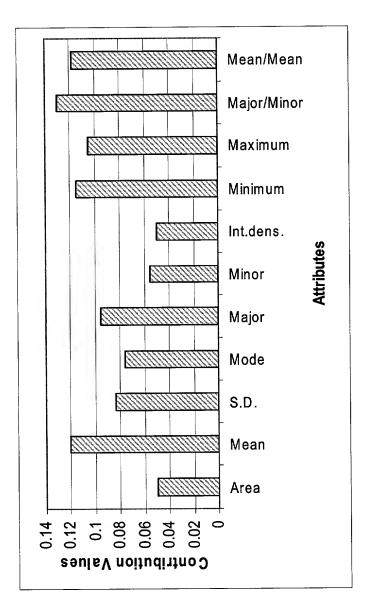


Figure 117: Contribution Values of Attributes Utilized in Designing AlignmentNet 3

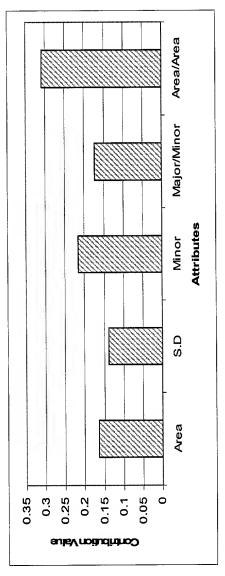


Figure 118: Contribution Values of Attributes Utilized in Designing ModCrossNet 1

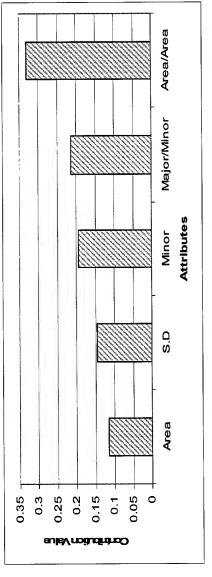


Figure 119: Contribution Values of Attributes Utilized in Designing ModCrossNet 2

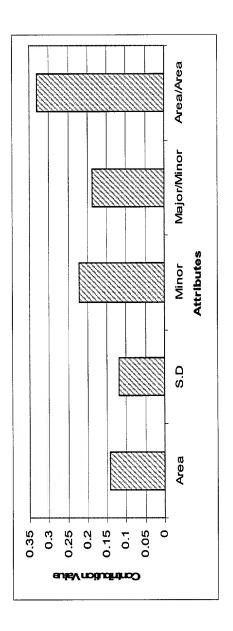


Figure 120: Contribution Values of Attributes Utilized in Designing ModCrossNet 3

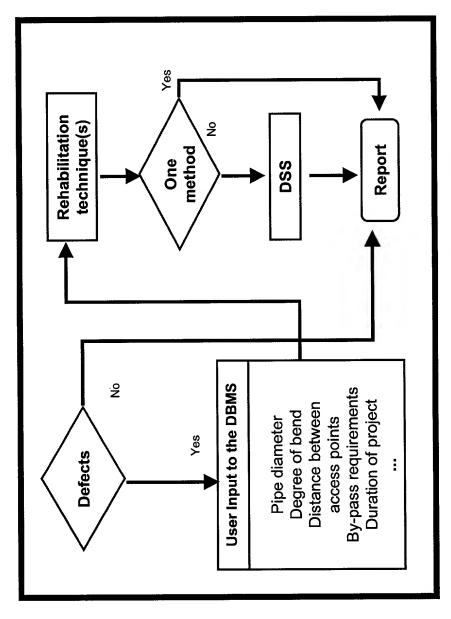


Figure 4-1: Developed Rehabilitation system

■ products: Table		
Field Name	Data Type	S. Destription
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Method of repair	Text	Commercial name of rehabilitation technique
Maximum distance between access points	Number	Maximum allowable distance between access points to the host pipe
Maximum degree of bends	Number	Maximum degree of bends of the host pipe
Average cost	Number	Cost of product
Average duration	Number	Duration to install 500 (m) of pipe in weeks
Number of years in business	Number	Years in business of supplier
Life expectency	Number	Design life of new pipe
Local experience	Text	Does the supplier have an Office in Canada
Access type	Text	Type of access required to the host pipe
Ength of product installed	Number	Number of KM of product installed by the supplier
Inovation	Number	Ability of supplier to accomodate none standard designs
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Figure 4-2: Products Table

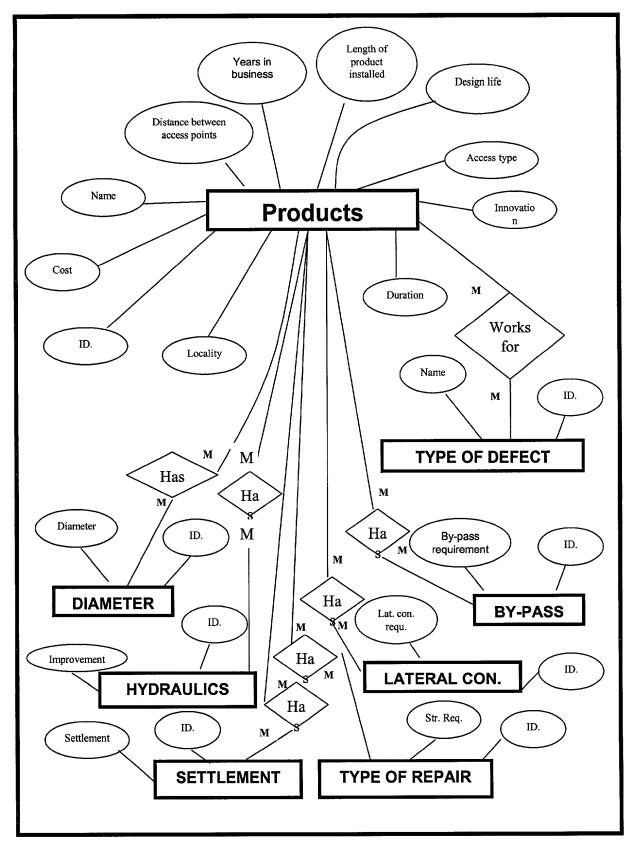


Figure 4-3: Entity Relationship Diagram

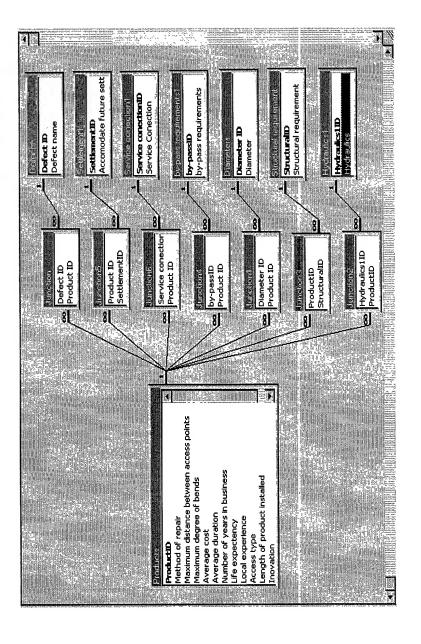
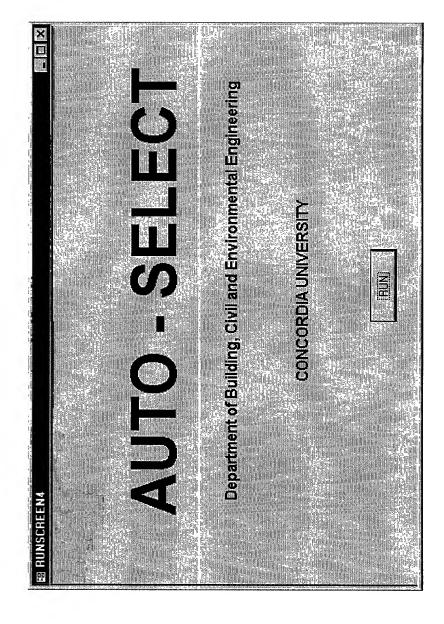


Figure 4-4: Schema of the Developed Database

Figure 4-5: Database Execution Form



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Figure 4-6: Data Entry and Retrieval Form

Which attributes do you want to consider in your analysis	∏ Years in business	☐ Length of product installed	☐ Innovation	Next	
	Cost	☐ Duration	☐ Life expectancy		

Figure 4-7: Available Attributes to Users

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Figure 4-8: Sample Dialog Screen

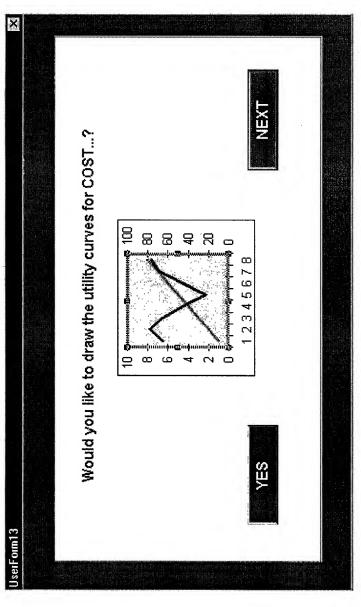


Figure 4-9: Plotting of Utility Functions

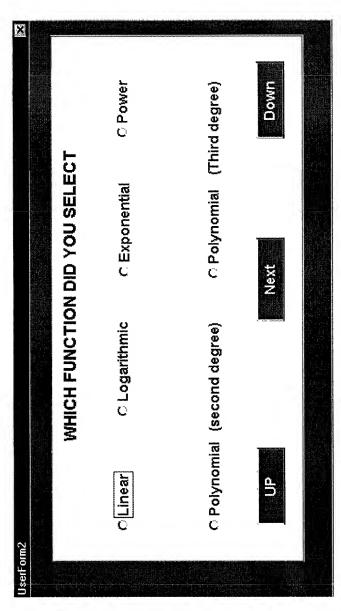


Figure 4-10: Selection of Utility Functions

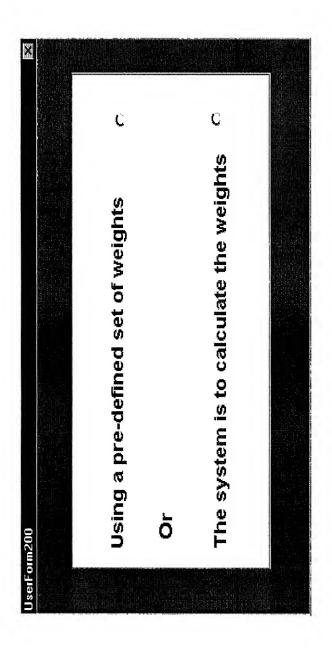


Figure 4-11: Selection of Required Mode of Weight Calculation

Figure 4-12: Feeding a Pre-Calculated Set of Weights

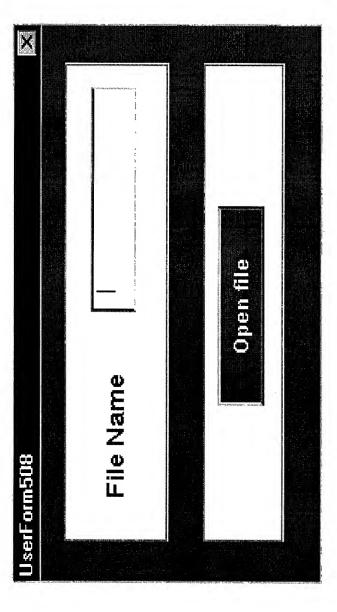


Figure 4-13: Retrieving a Pre-Defined Set of Weights

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Figure 4-14: Relative Importance Screen

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Innovation	Weight	
Calculate	Revise Next	Save

Figure 4-15: Weight Calculation Screen

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126	OVER	Alternative # 1	Alternative #2	Alternative #3	Alternative #4	
UserForm126						

Figure 4-16: Overall Utility Values